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REGULAR SUPPRESSION OF P,T-VIOLATING NUCLEAR MATRIX ELEMENTS

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Abstract

In heavy nuclei there is a parametrical suppression, $\sim A^{-1/3}$, of T-odd, P-odd matrix elements as compared to T-even, P-odd ones.

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Experimental searches for T-odd, P-odd (TOPO) effects in nuclei are planned now by many groups. To get an idea of their sensitivity one has to estimate typical value of TOPO mixing matrix elements in nuclei.

Detailed numerical studies [1, 2] (see also [3]) have demonstrated that TOPO nuclear matrix elements are regularly smaller than T-even, P-odd (TEPO) ones. This short note contains a simple intuitive explanation of this suppression.

We will confine here to a phenomenological treatment of both TEPO and TOPO interactions. In this approach the effective T-even, P-odd potential for an external nucleon is presented in a contact form in the spirit of the Landau-Migdal approach:

$$W = \frac{G}{\sqrt{2}}\,\frac{g}{2m}\,\{\vec{\sigma}\vec{p}, \rho(r)\} = \frac{G}{\sqrt{2}}\,\frac{g}{2m}\,\vec{\sigma}[\vec{p}\rho(r) + \rho(r)\vec{p}\,]. \tag{1}$$

Here $\{\ ,\ \}$ denotes anticommutator, $G = 1.027 \cdot 10^{-5} m^{-2}$ is the Fermi weak interaction constant, m is the proton mass, $\vec{\sigma}$ and $\vec{p}$ are respectively spin and momentum operators of the valence nucleon, $\rho(r)$ is the density of nucleons in the core normalized by the condition $\int d\vec{r}\rho(r) = A$ (the atomic number is assumed to be large, $A \gg 1$). A dimensionless constant g characterizes the strength of the P-odd nuclear interaction. It is an effective one and includes already the exchange terms for identical nucleons. This constant includes also additional suppression factors reflecting long-range and exchange nature of the P-odd one-meson exchange, as well as the short-range nucleon-nucleon repulsion. Its typical value is

$$g \sim 1. \tag{2}$$

Quite analogously, the effective T-odd, P-odd interaction of an external nucleon with core can be written as

$$W = \frac{G}{\sqrt{2}}\,\frac{\xi}{2m}\,i\,[\vec{\sigma}\vec{p}, \rho(r)] = \frac{G}{\sqrt{2}}\,\frac{\xi}{2m}\,\vec{\sigma}\,\vec{\nabla}\rho(r) \tag{3}$$

where $[\ ,\ ]$ denotes commutator, and ξ is the dimensionless characteristic of this interaction. The upper limit on the electric dipole moment of the mercury isotope ^{199}Hg set in the atomic experiment [4]

$$d(^{199}Hg)/e < 9.1 \cdot 10^{-28}\,cm \tag{4}$$

bounds this constant as follows:

$$\xi < 1.7 \cdot 10^{-3}. \tag{5}$$

We are going now to compare nuclear matrix elements of $\{\vec{p}, \rho(r)\}$ and $[\vec{p}, \rho(r)]$. Let us note first of all that a heavy nucleus is a semiclassical system, the corresponding large parameter being $A^{1/3}$. Since the anticommutator has a classical limit and the commutator does not, it is only natural to expect that the matrix element of the commutator is suppressed just by this parameter as compared to that of anticommutator.

Indeed, a simple-minded estimate for the T-even matrix element is

$$\langle\{\vec{p}, \rho(r)\}\rangle \sim 2\,\rho_0\,p_F \sim 3\,\rho_0\,r_0^{-1}. \tag{6}$$

Here ρ_0 is the nuclear density, p_F is the Fermi momentum, $r_0 = 1.2$ fm.

Somewhat more intricate is the T-odd case. Assuming for the core density a step-like profile

$$\rho(r) = \rho_0 \, \theta(R - r), \tag{7}$$

we get

$$\langle \vec{\nabla} \rho(r) \rangle \sim \rho_0 \, \Re^2 R^2 \tag{8}$$

where $R = r_0 \, A^{1/3}$ is the nuclear radius, $\Re$ is the value of the radial wave function of a valence nucleon at $r = R$. The following estimate is well-known [5]

$$\Re^2 R^3 \approx 1.5$$

(it means in fact that the nucleon density at the boundary constitutes one half of the internal one). In this way we get

$$\langle \vec{\nabla} \rho(r) \rangle \sim 1.5 \, \rho_0 \, r_0^{-1} A^{-1/3}. \tag{9}$$

Of course, the numerical factors in formulae (6), (9) should not be taken too seriously. However, the parametrical suppression of the T-odd effect $\sim A^{-1/3}$ gets obvious.

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